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Phytoliths of temperate forest-steppe: A case study from the Altay, Russia

Marina Silantyeva [a], Marina Solomonova [a], Natalya Speranskaja [a], Mikhail S. Blinnikov [b,c,*]

[a] Faculty of Biology, Altay State University, Barnaul 656049, Altaysky Kray, Russia
[b] Department of Geography and Planning, St. Cloud State University, St. Cloud, MN 56301-4498, USA
[c] Laboratory of Archaeometry, Kazan Federal University, Kazan, 420008, Tatarstan, Russia

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ABSTRACT

Phytoliths are a useful paleoproxy in arid environments. This modern analog study assessed variability of silica phytoliths in 30 species of grasses and 42 modern soil samples from eight locations in the Altaysky Kray and the Republic of Gorny Altay of Russia. Phytoliths were grouped into 25 broadly defined morphotypes based on their 3D shapes under light microscope and presumed anatomical origin within the plant. Grasses exhibited the most diverse forms. Forests, meadows, and steppes can be distinguished based on differences in proportion of various morphotypes. Steppes can be reliably identified based on high proportion of rondel phytoliths, but low presence of lobate and lanceolate forms. Meadows have high proportion of lobate and lanceolate forms. All forests have high proportion of smooth long cells and lanceolate phytoliths. Coniferous forests additionally have small presence of blocky forms with pitted surface and pores from conifers. Phytolith assemblages were also found to vary with gradients of temperature and precipitation, which could enable direct paleoenvironmental inferences from phytoliths in geological sediments from the region. However, vegetation types could not be differentiated based on the presence of particular types of trichomes, as has been suggested for other regions in Russia.

1. Introduction

Phytolith analysis has become a mature method of paleoenvironmental analysis along with pollen and macrofossil analyses (Blinnikov, 2013; Piperno, 2006). It is generally accepted that any paleoenvironmental reconstructions using phytoliths must begin with analyzing phytoliths in living plants and modern soils in the region of interest (Carnelli et al., 2001; Lu and Liu, 2003; Blinnikov, 2005), although studies of phytoliths in modern soils are less common than studies of phytoliths in plants. Despite recent advances in phytolith taphonomy (Albert et al., 2006; Fishkis et al., 2010; Blinnikov et al., 2013; Cabanes and Shahack-Gross, 2015), our understanding of how soil phytolith assemblages are formed and preserved is still very preliminary. At the same time, paleostudies demonstrate the ability of phytolith analysis to answer questions about past composition of plant communities, and so advances in modern phytolith studies are relevant.

We studied phytoliths in plants and modern soils of the Russian Altay, a continental ecotonal region located in the heart of Eurasia and an area of high significance to anthropology (Derevianko and Shunkov, 2002; Reich et al., 2010), paleoecology (Baker et al., 1993; Blyakharchuk et al., 2007), indigenous culture (Balakina and Balakina, 2014), and conservation efforts (Li et al., 2016). While phytoliths in modern soils in Europe (Novorossova, 1951; Smithson, 1958; Golyeva et al., 1987; Kamanina, 1992; Carnelli et al., 2001; Delhon et al., 2003), China (Lu et al., 2006; Song et al., 2012; Traoré et al., 2015), tropical Africa (Barboni et al., 1999; Brémond et al., 2008; Wooller et al., 2003; Neumann et al., 2017), and North America (Fredlund and Tieszen, 1997; Kerns, 2001; Blinnikov, 2005; Blinnikov et al., 2013; McCune et al., 2015) have received much attention, there have been fewer attempts in Siberia (Gavrilov and Golyeva, 2014; Gavrilov and Loyko, 2016), of which the Altay forms narrow southwestern edge.

Previous studies prove that phytoliths are robust proxies in ecotonal studies at the interface of forest and steppe (Witty and Knox, 1964; Verma and Rust, 1969; Blinnikov et al., 2013). First, grasses (Poaceae), which contain an order of magnitude more biogenic silica than trees (Geis, 1973; Piperno, 2006), are abundant in such areas. Short grass cells are considered diagnostic at least to the subfamily level (Neumann et al., 2017). Detection of forest vs. grassland communities can sometimes be made merely by studying the total opal concentration in modern soils (Wilding and Drees, 1971; Blinnikov, 2005). Second, forest-steppes typically span the dry end of the moisture gradient, with few lakes or peat bogs available for pollen analysis. Finally, at least in Eurasia, forest-steppe is of great interest to archeologists, because this has been a transitional zone between more sedentary forest cultures and more nomadic steppe cultures with uncertain boundaries between the two.

In higher plants of temperate northern Eurasia, phytoliths have been mostly studied in grasses (Kiseleva, 1982, 1992), sedges (Bobrov et al., 2016), conifers (Carnelli et al., 2004), and some dicotyledonous shrubs

* Corresponding author.
E-mail address: msblinnikov@stcloudstate.edu (M.S. Blinnikov).

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